HS-ETS-ED Engineering Design

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Students who demonstrate understanding can:

a. Ask questions and collect information to quantify the scope and impacts of a major global problem on local communities and find evidence of possible causes by breaking the problem down into parts and investigating the mechanisms that may contribute to each part. [Clarification Statement: For example, students ask questions to quantify the scope and impacts of acid rain in a local community by investigating the mechanisms involved in stone monument erosion.] [Assessment Boundary: Limit to asking questions and gathering information to better understand the problem and possible causes; not finding solutions.]

b. Analyze input and output data and functioning of a human-built system to define opportunities to improve the system's performance so it better meets the needs of end users while taking into account constraints (e.g., materials, costs, scientific principles). [Clarification Statement: Analyze data and functioning of a human-built system such as a school's heating and cooling system; or throughput and functioning of a city's wastewater system.]

c. Evaluate different solutions to a problem by identifying criteria (e.g., cost, safety, reliability, aesthetics) and possible impacts on society and the natural environment, and using a trade-off matrix or numerical weighting system to choose the best solution. [Clarification Statement: Example problems for which multiple solutions can be proposed and evaluated include deicing a parking lot, increasing yield of a garden or farm, or mining a natural resource with minimal environmental damage.]

d. Plan and carry out a quantitative investigation with physical models or prototypes to develop evidence on the effectiveness of design solutions, leading to at least two rounds of testing and improvement. [Clarification Statement: For example, physical models or prototypes to conduct a quantitative investigation to determine if an ultraviolet light can purify water equally well as a chlorine-based system.]

e. Use computational thinking to create, simulate, and compare different design solutions, checking to be certain that the simulation makes sense when compared with the real world. [Clarification Statement: For example, students create a computer simulation of a model building to see how different modifications could save energy and reduce CO_2 emissions.] [Assessment Boundary: Students use existing modeling software.]

f. Refine a solution by prioritizing criteria and taking into account the life cycle of a given product or technological system and factors such as safety, reliability, and aesthetics to achieve an optimal solution. [Clarification Statement: For example, choose the best possible heat pump technology for a campus building; determine the optimum method for extracting oil and natural gas; or best method for treating soil prior to planting crops.]

The performance expectations above were developed using the following elements from the NRC *A Framework for K – 12 Science Education*:

Science and Engineering Practices

Asking Questions and Defining Problems
Asking questions and defining problems in grades 9–12 builds from grades K–8 experiences and progresses to formulating, refining, and evaluating empirically testable questions and explanatory models and simulations.
- Ask questions that arise from phenomena, models, theory, or unexpected results. (a)
- Ask questions to determine quantitative relationships between independent and dependent variables. (a)

Planning and Carrying Out Investigations
Planning and carrying out investigations to answer questions or test solutions to problems in 9 – 12 builds on k – 8 experiences and progresses to include investigations that build, test, and revise conceptual, mathematical, physical, and empirical models.
- Plan and carry out investigations collaboratively and test designs as part of building and revising models, explaining phenomena, or testing solutions to problems. Consider possible confounding variables or effects, and ensure that the investigation's design has controlled for them. (d)
- Select appropriate tools to collect, record, analyze, and evaluate data. (d)

Analyzing and Interpreting Data
Analyzing data in 9–12 builds on K–8 and progresses to introducing more detailed statistical analysis, the comparison of data sets for consistency, and the use of models to generate and analyze data.
- Use tools, technologies, and models (e.g., computational, mathematical) to generate and analyze data in order to make valid and reliable scientific claims or determine an optimal design solution. (b)

Using Mathematics and Computational Thinking
Mathematical and computational thinking at the 9–12 level builds on K–8 and progresses to using algebraic thinking and analysis, a range of linear and nonlinear functions including trigonometric functions, exponentials and logarithms, and computational tools for statistical analysis to analyze, represent, and model data. Simple computational simulations are created and used based on mathematical models of basic assumptions.
- Use simple limit cases to test mathematical expressions, computer programs or algorithms, or simulations to see if a model makes sense by comparing the outcomes with what is known about the real world. (e)

Constructing Explanations and Designing Solutions
Constructing explanations and designing solutions in 9–12 builds on K–8 experiences and progresses to explanations and designs that are supported by multiple and independent

Disciplinary Core Ideas

ETS1.A: Defining and Delimiting an Engineering Problem
- Design criteria and constraints, which typically reflect the needs of the end-user of a technology or process, address such things as the product's or system's function (what job it will perform and how), its durability, and limits on its size and cost. (b)
- Criteria and constraints also include satisfying any requirements set by society, such as taking issues of risk mitigation into account, and they should be quantified to the extent possible and stated in such a way that one can tell if a given design meets them. (b)
- Humanity faces major global challenges today, such as the need for supplies of clean water and food or for energy sources that minimize pollution, which can be addressed through engineering. These global challenges may also have manifestations in local communities. But, whatever the scale, the first things that engineers do is define the problem and specify the criteria and constraints for potential solutions. (a)

ETS1.B: Developing Possible Solutions
- To design something complicated one may need to break the problem into parts and attend to each part separately but must then bring the parts together to test the overall plan. (a)
- When evaluating solutions, it is important to take into account a range of constraints, including cost, safety, reliability, and aesthetics, and to consider social, cultural, and environmental impacts. (c)
- Testing should lead to improvements in the design through an iterative procedure. Both physical models and computer models can be used in various ways to aid in the engineering design process. Physical models, or prototypes, are helpful in testing product ideas or the properties of different materials. (d)
- Computer models are useful for a variety of purposes, such as in representing a design in 3-D through CAD software; in troubleshooting to identify and describe a design problem; in running simulations to test different ways of solving a problem or to see which one is most efficient or economical; and in making a persuasive presentation to a client about how a given design will meet his or her needs. (e)

ETS1.C: Optimizing the Design Solution
- The aim of engineering design is not simply to find a solution to a problem but to design the best solution under the given constraints and criteria. Optimization can be complex for a design problem with numerous desired qualities or outcomes. Criteria may need to be broken down into simpler ones that can be approached systematically, and decisions about the priority of certain criteria over others (trade-offs) may be needed. (f)
- The comparison of multiple designs can be aided by a trade-off matrix. Sometimes a numerical weighting system can help evaluate a design against multiple criteria. When evaluating solutions, all relevant considerations, including cost, safety, reliability, and aesthetic, social, cultural, and environmental impacts, should be

Crosscutting Concepts

Cause and Effect
Empirical evidence is required to differentiate between cause and correlation and make claims about specific causes and effects. Cause and effect relationships can be suggested and predicted for complex natural and human designed systems by examining what is known about smaller scale mechanisms within the system. Systems can be designed to cause a desired effect. Changes in systems may have various causes that may not have equal effects. (a),(e)

Systems and System Models
Systems can be designed to do specific tasks. When investigating or describing a system, the boundaries and initial conditions of the system need to be defined and their inputs and outputs analyzed and described using models. Models (e.g., physical, mathematical, computer models) can be used to simulate systems and interactions within and between systems at different scales. Models can be used to predict the behavior of a system, but these predictions have limited precision and reliability due to the assumptions and approximations inherent in models. (b),(c),(d)

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Connections to Engineering, Technology, and Applications of Science

Influence of Engineering, Technology, and Science on Society and the Natural World
Modern civilization depends on major technological systems, such as agriculture, health, water, energy, transportation, manufacturing, construction, and communications. Engineers continuously modify these systems to increase benefits while decreasing costs and risks. New technologies can have deep impacts on society and the environment,

HS-ETS-ED Engineering Design

HS-ETS-ED Engineering Design *(continued)*		
student-generated sources of evidence consistent with scientific knowledge, principles, and theories. ▪ Apply scientific knowledge to solve design problems by engaging in all steps of the design cycle, taking into account possible unanticipated effects. (f) **Engaging in Argument from Evidence** Engaging in argument from evidence in 9–12 builds from K–8 experiences and progresses to using appropriate and sufficient evidence and scientific reasoning to defend and critique claims and explanations about the natural and designed world. Arguments may also come from current scientific or historical episodes in science. ▪ Evaluate the merits of competing arguments, design solutions and/or models. (c)	included. (c) ▪ Testing should lead to design improvements through an iterative process, and computer simulations are one useful way of running such tests. (d)	some that were not anticipated. Analysis of costs and benefits is a critical aspect of decisions about technology. (c),(f)

Connections to other DCIs in this grade-level: **HS.ESS-CC, HS.ESS-HS, HS.PS-E, HS.ETS-ETSS**

Articulation to DCIs across grade-levels: **MS.ETS-ED**

Common Core State Standards Connections: [Note: these connections will be made more explicit and complete in future draft releases]

ELA –

RST.9-10.3 Follow precisely a complex multistep procedure when carrying out experiments, taking measurements, or performing technical tasks, attending to special cases or exceptions defined in the text.

RST.9-10.7 Translate quantitative or technical information expressed in words in a text into visual form (e.g., a table or chart) and translate information expressed visually or mathematically (e.g., in an equation) into words.

RST.11-12.3 Follow precisely a complex multistep procedure when carrying out experiments, taking measurements, or performing technical tasks; analyze the specific results based on explanations in the text.

WHST.9 Draw evidence from informational texts to support analysis, reflection, and research.

Mathematics –

MP.2 Reason abstractly and quantitatively
MP.4 Model with Mathematics
MP.5 Use appropriate tools strategically
8.F Define, evaluate, and compare functions.
S.ID Summarize, represent, and interpret data on a single count or measurement variable
S.IC Make inferences and justify conclusions from sample surveys, experiments, and observational studies
F.BF Build a function that models a relationship between two quantities
F.LE Construct and compare linear, quadratic, and exponential models and solve problems
N-Q Reason quantitatively and use units to solve problems
A.CED Create equations that describe numbers or relationships.